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THE EFFECTS OF DUAL-STREAM COMMINGLED COLLECTION OF RECYCLABLES FROM HOUSEHOLDS IN SØNDERBORG, DENMARK

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ABSTRACT

One year after its introduction in the municipality of Sønderborg, the kerbside collection of commingled recyclable materials from households has significantly altered waste flows and treatment opportunities. This study evaluates the consequences of these changes and compares the performance of the previous and current waste management systems in the municipality in terms of primary energy and greenhouse gas emission savings.

In the new systems approx. 65% more materials are collected for recycling (an increase from 18% to 30% in the share of domestic household waste). The corresponding decrease in residual waste, which is used for energy production in the local waste CHP plant, is being compensated by import of industrial waste from northern Germany.

The results of this study credit the new management system with an increase of 8-26% in primary energy and 5-33% in GHG emissions savings over the old management system, depending on the exclusion/inclusion of implications related to imported waste amounts in the system analysis.

Keywords: Dual-stream collection, central sorting, waste management, GHG accounting

INTRODUCTION

The municipality of Sønderborg, placed in southern Jutland, with a population of approx. 76.000, has declared a vision of becoming CO₂ neutral and is taking steps to achieve this goal before 2029 [1]. These very high ambitions have also affected strategies regarding waste management and indeed the municipality has the long term objective of recycling nearly all arising waste. Waste from households accounts for approx. 92.000 tonnes/ year (domestic waste, garden waste, bulky and hazardous waste) of which domestic household waste is about 26.000 tonnes/ year. For a number of years already around 65% of total waste from households has been recycled, 29% combusted with energy recovery and around 6% landfilled. Recycling of domestic waste has however been rather low at around 20%.

This conference contribution reports on the performance evaluation of a new source separation, collection and treatment system implemented in the municipality for domestic waste, in 2012. Central to this system is the kerbside collection of commingled recyclable materials in a dual-stream (DuoFlex collection system), followed by their separation and sorting in a specialized plant. The dual-stream collection constitutes of (1) a mixed stream of paper, cardboard and plastic foils, and (2) a mixed stream of glass, metals and hard plastic containers. The two are collected together in a dual chamber kerbside bin, and with the use of specific dual-compartment collection trucks.

The previous collection system in the municipality constituted of (1) a large number of public collection points, i.e. a cube system, for separated glass, paper and metal cans; (2) kerbside collection of domestic residual waste, and (3) a number of 8 recycling centers, where citizens drove and delivered a variety of wastes, including glass, paper, cardboard, metals and plastics. While the recycling centers are still available in the new system, the number of public collection points has been reduced by 2/3.

The present study has combined the methods of material flow analysis (MFA), cumulated energy balance and consequential LCA (Global warming impact assessment) to compare the previous and current management systems in the municipality, with a focus on the effects and implications of applied changes.

METHODS

Scope and functional unit

The functional unit is defined as management, including collection, transport, treatment and final disposal of eventual residues, of the annual generated amount of domestic household waste in the municipality. Domestic household waste is defined similarly as in Danish legislation, and consists of domestic residual waste and materials for recycling discarded by households. However this definition has been extended to include all material fractions affected by the new curbside collection scheme, i.e. paper, cardboard, glass, plastic packaging and metals, whereas the latter two fractions are part of bulky waste category in the Danish waste reporting system.

The results of this assessment are expected to be valid in a short term perspective alone and thus reflect conditions in 2013. Source segregation efficiencies and therefore recycling is expected to still grow considerably as the new collection system matures (based on experience with the introduction of the same system in other Danish municipalities). The geographical scope considered includes the municipality and extends to Denmark and surrounding countries through affected systems and secondary material processing.

Global warming impact and cumulated energy demand assessment

The assessment is performed according to consequential LCA methodology [2], whereby the systems evaluated are expanded and credited with savings of marginal background energy and virgin material production. The main objective is to reflect the implications of changing the waste management system, within the defined scope, and therefore the new system was also expanded to include other systems affected by these changes.

According to the used LCA methodology, global warming (GW) impact (expressed in kg CO₂ eq.) aggregates the impact of GHG emissions over 100 years horizon, which is the time span usually used in environmental assessments of waste systems. The calculation was performed by using the Danish EDIP 2003 method, with updated characterization factors [3], facilitated by the LCA software SimaPro 7.3.3. Cumulated energy demand (CED) factors (expressed in MJ eq. or MJ primary) were calculated for all operations, processes and flows (induces and avoided) included in the system boundaries. CED factors account for the cumulated energy spent to produce energy or materials. For example for electricity from coal it would account for energy spent in extraction, refining, provision of fuels, supplementary fuel used for start-up operations and energy conversion in the power plant. The CED method is also available in the SimaPro 7.3.3. software.

Marginal electricity production in a short term perspective is assumed to be from coal condensing power plants [4]. The heat production marginal is specific to the local distribution network to which a WtE plant is connected, and in the case of the Sønderborg CHP plant heat output to the district heating is replacing utilization of natural gas. The same was assumed for the other two affected plants (described in the section on energy recovery).

Material flow analysis

The description of the two systems assessed here was performed by mass flow analysis. The yearly flow of materials in 2011 and 2012 respectively, through the systems, has been identified at material fraction level from the point of waste generation to the point of delivery of recovered materials to reprocessing plants. This has been supplemented with literature data covering reprocessing/recycling in order to arrive at the point of material substitution. In the systems the composition of domestic residual waste was unknown but crucial to investigate in order to:

- Determine the efficiency of source segregation of recyclables and the potential left in the residual bin;
- Model energy conversion processes, including energy, emissions and material recovery (metals) from combustion residues.

The municipality has for these reasons commissioned a waste characterization study in 2013, covering analysis of residual waste from three different types of housing: residential neighborhood, terraced houses and apartment buildings. Two of the authors of this contribution have actively been involved in this study. The composition determined in this study allowed, under the assumption of similar quantities of waste being generated both in 2011 and 2012, to estimate the profile of residual waste in the old system.

Finally, the knowledge on the fraction composition of the waste in the two systems was supplemented with chemical characterization of individual fractions, particularly calorific value and fossil carbon content, determined previously for Danish waste [5].

SYSTEM DESCRIPTION

Residual waste composition

The residual waste composition determined by characterization for the new system and estimated for the old system is presented in table 1.

Table 1: Composition of the residual bin in 2011 and 2012 and characterization of waste fractions

Fractions	Residual bin 2011 [% w.w.]	Residual bin 2012 [% w.w.]	LHV [MJ/kg TS]	H ₂ O [% w.w.]	TS [% w.w.]	C-biogenic [% w.w.]	C-fossil [% w.w.]
Food waste	38.7	45.1	19.5	73.0	27.0	13.5	0.1
Garden waste	3.0	3.4	14.0	50.6	49.4	20.9	0.4
Recyclable paper	8.3	3.2	13.7	9.1	90.9	34.1	0.2
Recyclable cardboard	5.5	2.2	15.0	20.5	79.5	32.5	0.2
Foil plastics	1.2	0.8	40.1	14.1	85.9	0.4	70.1
Plastic containers	3.4	3.4	37.1	5.9	94.1	0.4	74.0
Other of plastic	0.5	0.6	31.6	5.5	94.5	7.7	56.7
Metal containers	2.2	1.4	1.0	12.0	88.0	1.7	0.0
Other of metal	0.4	0.4	0.0	8.3	91.7	0.0	0.0
Glass containers	2.6	1.0	0.0	11.7	88.3	0.0	0.0
Rest residual	34.3	38.5	23.1	21.9	78.1	18.4	23.9

Mass flows and system expansion

Simplified process flow diagrams, containing mass balance information are illustrated in Fig 1. The change from the old system to the new has determined a significant change in material flows and also has affected other surrounding systems. Seen in isolation, in the new system approx. 12% of generated domestic waste has been diverted from thermal treatment towards recycling.

Having less waste for the WtE CHP plant comes however in conflict with the municipality's strategy to increase energy production from renewable sources including waste. Furthermore, the WtE plant is bound by contracts to deliver heat for district heating. Under these conditions, the import of industrial waste (mainly wood waste) from northern Germany (started in 2012), in an amount approx. equivalent to the missing residual waste, can be considered an indirect effect of the new waste management system in the municipality. In a consequential LCA this effect should be included (at least in a short term perspective) in the assessment. The waste imported would have otherwise been transported and used in one of the WtE CHP plants in Hamburg. An inquiry in the operation conditions of these plants revealed that they are also bound by contracts to deliver, uninterrupted, heat in the form of district heating or steam to households and industry respectively. The waste imported in Denmark therefore induces a cascading effect, whereby the missing energy has to be provided in Hamburg from other sources. Two situations were modeled in this study: (1) the missing energy is provided from background marginal electricity and heat production and (2) and equivalent (energy content basis) quantity of waste is imported to Hamburg. In the latter case, the waste imported is assumed to be MSW which would have been otherwise landfilled in Poland. Combustible industrial waste is more than likely a limited resource and therefore the "marginal" for waste can be considered potentially combustible waste which is landfilled today.

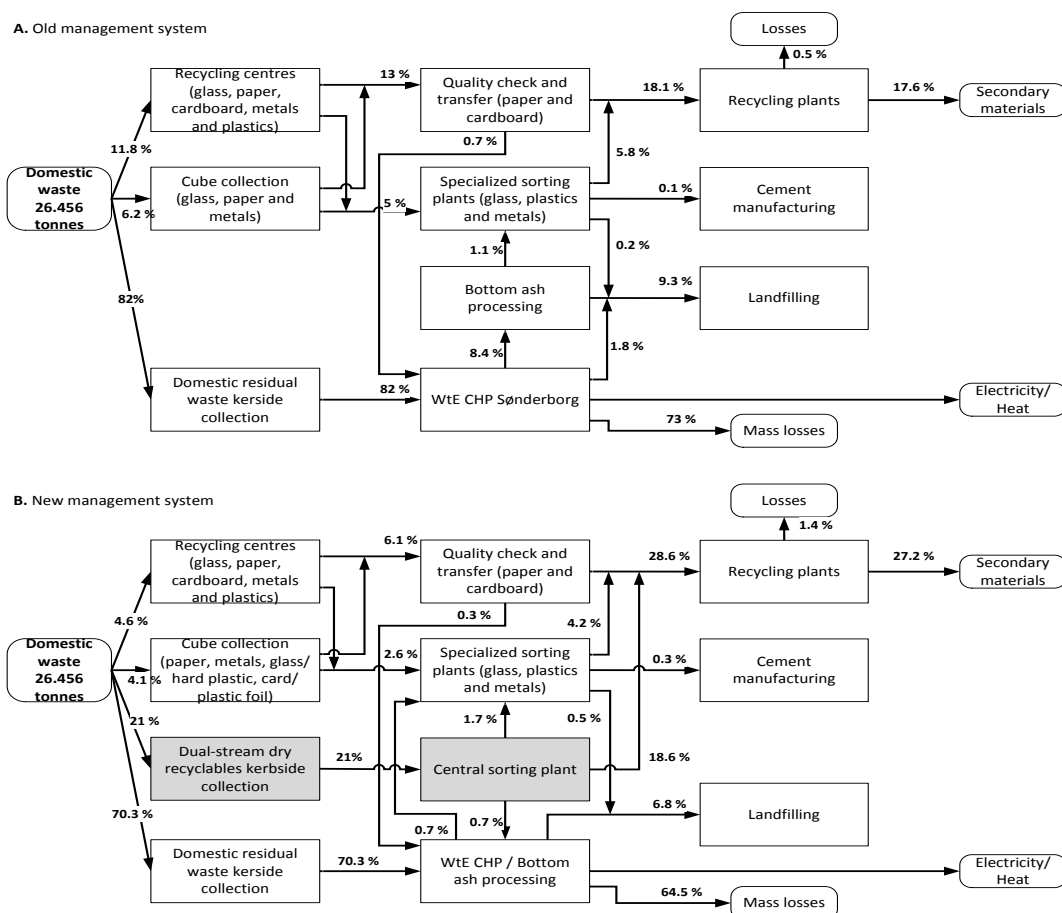


Figure 1: Mass flows [%] in the old (A) and new (B) waste management systems

Collection and transport

Data on collection of residual waste and kerbside recyclables has been provided from the accounting done by the collection company. Transportation from the local sorting facility and the central sorting plant to further processing and recycling plants has been included. The transport by citizens of waste collected at recycling centers is not included. Transportation of sorting residues and combustion residues has also been accounted. When the system is extended to include imported waste additional transportation needs have to be accounted, including for imported waste from northern Germany to Sønderborg, imported waste from Poland to Hamburg, both accounted as diesel consumption by long-haul trucks.

Material sorting and reprocessing

In the new system the commingled dual-stream recyclables are sent to a central sorting facility which receives this type of waste from a number of municipalities in southern Jutland. The sorting plant has two separate lines, one for the paper/card/foil fraction and one for the glass/metal/hard plastic fraction. The first fraction is sorted manually while the second is done mostly automatically with the use of magnetic, eddy current and NIR sorting equipment. Recyclable materials collected at the recycling centers and in the cube system were sorted (quality checked) and bailed before delivery to reprocessing plants in a local facility, in the old system. This has been maintained in the new system with the exception of glass and hard plastic (collected mixed) from the cube system which is now sent to the central sorting facility.

Combustion residues from the waste CHP plant included in the system are bottom ash and APC residues. Bottom ash is processed locally to recover metals and the remaining inert fraction is mostly used as aggregate in the construction of roads, but was here modeled as landfilled. APC residues are hazardous waste and are sent for disposal to Germany where they are used for backfilling of old salt mines.

It was possible to partially identify where recovered materials are being sent for reprocessing/recycling. Glass, as full bottles for reuse and cullet for re-melting, is mostly recycled within Denmark. Paper and cardboard is used in the production of new paper or paper and cardboard packaging in Denmark or the neighboring countries (e.g. Sweden and Germany). Metals are sent to further sorting to scrap metal plants in Denmark, which further export the metals to other European countries but also Asia for final reprocessing to new products. Plastics are exported directly. Germany but also Asian countries are destinations for sorting and reprocessing. Sorting residues and reprocessing losses have been included. Quality losses have also been considered and therefore a substitution ratio is applied to primary materials. These parameters are presented in table 2.

Table 2: Losses across the material recovery chain and substitution ratios.

Material	Sorting losses [% input]	Reprocessing losses [% input]	Substitution ratio [% input]
Paper	5.0	2.9	100.0
Cardboard	5.0	5.5	90.0
Glass	1.0	0.0	100.0
Fe-metals	2.0	9.5	100.0
NF-metals	4.8	2.9	100.0
Plastics	25.00		80.0

Energy recovery

The waste CHP plant in Sønderborg is where the residual waste and sorting residues from the recycling centres and cube collection are treated. With a calculated gross efficiency of 19.5% for electricity and 87% for heat recovery based on the LHV of the input, this plant is highly efficient. The very high recovery of heat is due to the application of flue gas condensation. Net efficiencies, i.e. grid power output and heat sold to the district heating network in 2011, are 15.2% electricity and 84% heat respectively. Sorting residuals from the central sorting plant for the dual-stream recyclables are sent to Haderslev waste CHP which has a net electricity and heat efficiency of 16% and 49% respectively. When the system is expanded, one of the WtE plants in Hamburg has to be considered. It was chosen to use in the model the MVR, Rugenberger Damm plant, which displayed in 2011 net electricity and heat efficiencies of 7.3% and 53% respectively. The lower efficiency of this plant can be partly explained by the fact that heat is mainly delivered in the form of high temperature steam to nearby industry which limits electricity production. Lastly, the sorting and reprocessing residuals from plastic recycling are assumed to be utilized as substitute fuel in cement manufacturing in Germany, where they replace hard coal coke based on the energy content.

RESULTS AND CONCLUSION

The new kerbside collection system for recyclable materials implemented in the municipality of Sønderborg has determined an increase of 65% in materials collected for recycling (from 18% to 30%) in the first year of its implementation. The approx. 14% decrease in collected residual waste has freed combustion capacity in the local WtE CHP, which has determined the import of a corresponding quantity of waste from northern Germany. The WtE plant is an integral part of the municipalities' energy strategy, i.e. it will run for the foreseeable future, which means that changes in waste amounts due to changes in waste management, are/will determine the import/use of other waste for energy production. In a short term perspective, this creates a cascading effect, whereby if this additional waste was already used for energy, it will have to be replaced where it was originally used and so on. Eventually, this extra need for waste for energy, in perfect market conditions, should induce the use of waste which would otherwise be landfilled somewhere.

CED and GWP results in this study are illustrated in Fig 2. Positive values represent induced burdens while negative numbers represent credited benefits/savings. Results for the new waste management system are shown without system expansion to include imported waste (Fig. 2 – New system) and with the inclusion of imported waste and associated effects (Fig. 2 – New system 1 and 2).

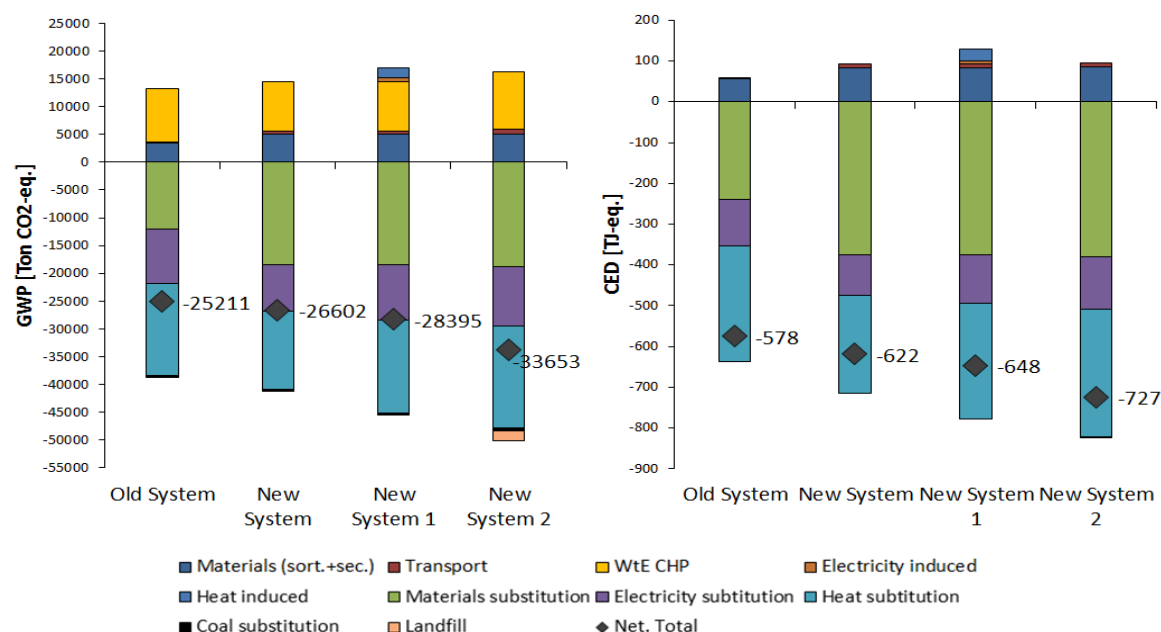


Figure 2: Overall CED and GWP results

The new management system in isolation achieves significant increases in both primary energy (8%) and GHG emission savings (5%), due to increased material recovery and recycling compared to the previous system in the municipality. If the system is expanded to include imported waste and the missing amount in Hamburg is assumed replaced by marginal energy production, a higher increase in savings is still demonstrated (Figure 2 – New system 1). This is due to the higher energy recovery efficiency in the Sønderborg WtE CHP compared to the avoided energy recovery in Hamburg. Lastly, if the missing amount of waste in Hamburg is instead modeled as inducing an import of waste which would have otherwise been landfilled, the system is credited with production of additional energy and avoiding landfill emissions (Fig. 2 – New system 2). These credits are much larger than induced transport and combustion emissions. In this way the new system displays an increase of approx. 26% in primary energy savings and 33% in GHG emissions compared to the old management system in the municipality.

In conclusion, this study shows that the introduction of kerbside collection of commingled recyclables, in a system previously based on public collection points, determined significant energy and climate benefits through increased material recycling. In addition, the implications on already existing waste treatment infrastructure was carefully considered and included in the system analysis. Diverting waste for recycling can free capacities for thermal treatment which can be used to treat additional waste. Ideally this should determine a move up the waste hierarchy and thus reduce waste disposal. The additional benefits gained due to these indirect effects are shown to be extensive.

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